Research of Damping and Dynamic Stress for Impeller of Reactor Coolant Pump

Long Abstract

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Abstract

Nuclear reactor coolant pump (RCP) is the equipment which provides the power to transfer of the coolant. Impeller as an important part of RCP needs to keep operating for a long stable and reliable time under high pressure and high temperature condition. In practical operation, fluctuation pressure caused by rotor stator interaction (RSI) is the main exciting load for impeller vibration which is a seriously threat to the high efficient and stable operation of RCP.

This paper investigated the damping and dynamic stress of impeller. The damping consists of material damping of structure and hydrodynamic damping of fluid. Mode analysis method is used to calculate mode shape of impeller. The material damping formulated with Lazan damping model [1] is related to stress level. The hydrodynamic damping of a specific mode shape is the ratio of fluid dissipated energy to the structural maximum strain energy [2]. The fluid dissipated energy can be obtained by fluid structure coupling method [3]. The fluid boundary surface is moving periodically as the mode shape of impeller. The hydrodynamic exciting force which applies on blades and shroud are the main load for impeller vibration. The results showed that the material damping and hydrodynamic damping vary with the mode of impeller. The hydrodynamic damping nearly remains constant when the amplitude of mode shape changes in the range of small amplitude and is much bigger than the material damping by one order of magnitude. So the material damping can be neglected when calculating the impeller dynamic stress.

The unsteady pressure load is obtained using the time accurate CFD simulation. The fluid flow was numerically simulated based on the standard k-epsilon turbulence model. The pressure result in time domain can be transformed to frequency-domain using Discrete Fourier Transform (DFT). The research showed that the impeller is subject to the load with different frequencies. The blade passing frequency caused by vanes and the rotational frequency are the main frequency of pressure at the outlet of impeller. The rotational frequency is the main frequency of pressure while blade passing frequency has less effect at the inlet of impeller. The pressure result on blades and shroud surfaces of impeller will be used in the structure analysis. The amplitude and phase of pressure load at a particular frequency are applied to corresponding location of impeller. Finally, the harmonic response analysis method is used to calculate the displacement and stress responses of the impeller.

According to the damping ratio and pressure load, the dynamic response from different frequency can be obtained.

This paper establishes a complete analysis system of damping and dynamic stress. The analysis process can provide a theoretical suggestion for the design and manufacture of impeller. According to this analysis process, it can help to confirm whether the impeller can keep operating for a long stable and reliable time in the high temperature, high pressure environment.

References

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